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APPLICATION FOR LETTERS PATENT

for

METHOD OF REDUCING ELECTRICAL SHORTS FROM THE BIT LINE TO THE CELL PLATE

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TITLE OF THE INVENTION
METHOD OF REDUCING ELECTRICAL SHORTS
FROM THE BIT LINE TO THE CELL PLATE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a divisional of application Serial No. 09/399,592, filed September 20, 1999, pending.

TECHNICAL FIELD OF THE INVENTION

[0002] This invention relates generally to the formation of a bit line over capacitor array of memory cells.

BACKGROUND OF THE INVENTION

[0003] This invention was principally motivated in addressing problems and improvements in dynamic random access memory (DRAM). As DRAM increases in memory cell density, there is a continuing challenge to maintain sufficiently high storage capacitance despite decreasing cell area. Additionally, there is a continuing goal to further decrease cell area. One principal way of increasing cell capacitance is through cell structure techniques. Such techniques include three-dimensional cell capacitors, such as trenched or stacked capacitors. Yet as feature size continues to become smaller and smaller, development of improved materials for cell dielectrics, as well as the cell structure, is important.

[0004] Conventional stacked capacitor DRAM arrays utilize either a Capacitor Over Bit line (COB) or a Capacitor Under Bit line (CUB) construction. With a Capacitor Over Bit line construction, the bit line is provided in close vertical proximity to the bit line contact of the memory cell field effect transistor (FET), with the cell capacitors being formed over the top of the word line and bit line. With a Capacitor Under Bit line construction, a deep vertical bit line contact is made through a thick insulating layer to the source/drain region of the cell FET access transistor, with the capacitor construction being provided over the word line and under the bit line.

[0005] The present invention relates to a method of reducing electrical shorts between the bit contact and the capacitor cell plate in a Capacitor Under Bit line cell.

SUMMARY OF THE INVENTION

[0006] The process of the present invention provides a method to prevent a short circuit between a capacitor cell plate and a conductive contact. The present invention provides for a capacitor structure having lower and upper conductive cell plates. The conductive cell plates are separated by a dielectric, and the conductive cell plates and the dielectric have exposed edges. A layer of TEOS is disposed upon the wafer and about the capacitor structure. The TEOS layer encases the exposed edges of the conductive cell plates. A conductive contact structure is then provided adjacent the capacitor structure. The TEOS layer separates the capacitor structure and the conductive contact structure, thereby preventing the conductive structures from shorting together.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0007] The present invention will be better understood from reading the following description of nonlimitative embodiments, with reference to the attached drawings, wherein:

[0008] Figure 1 is a schematic cross-section of a semiconductor wafer fragment, in accordance with the process of the present invention;

[0009] Figure 2 is a schematic cross-section of the semiconductor wafer fragment, in accordance with the process of the present invention;

[0010] Figure 3 is a schematic cross-section of the semiconductor wafer fragment, in accordance with the process of the present invention;

[0011] Figure 4 is a schematic cross-section of the semiconductor wafer fragment, in accordance with the process of the present invention;

[0012] Figure 5 is a schematic cross-section of the semiconductor wafer fragment, in accordance with the process of the present invention;

[0013] Figure 6 is a schematic cross-section of the semiconductor wafer fragment, in accordance with the process of the present invention;

[0014] Figure 7 is a schematic cross-section of the semiconductor wafer fragment, in accordance with the process of the present invention;

[0015] Figure 8 is a schematic cross-section of the semiconductor wafer fragment, in accordance with the process of the present invention;

[0016] Figure 9 is a schematic cross-section of the semiconductor wafer fragment, in accordance with the process of the present invention; and

[0017] Figure 10 is a schematic cross-section of the semiconductor wafer fragment, in accordance with the process of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Figures 1-10 illustrate a technique for eliminating electrical shorts in a semiconductor device. It should be understood that the illustrations are not meant to be actual cross-sectional views of any particular semiconductor device, but are merely idealized representations which are employed to more clearly and fully depict the formation of the process of the present invention than would otherwise be possible.

[0019] Referring to Figure 1, a semiconductor wafer fragment is indicated generally as a wafer 10. Wafer 10 is defined in part by a silicon semiconductor substrate 11. In the semiconductor industry, a “substrate” refers to one or more semiconductor layers or structures, which includes active or operable portions of semiconductor devices. In the context of this document, the term “semiconductor substrate” is defined to mean any construction comprising semiconductive material, including but not limited to bulk semiconductive material, such as a semiconductive substrate, either alone or in assemblies comprising other materials thereon, and semiconductive material layers, either alone or in assemblies comprising other materials. The term “substrate” refers to any supporting structure including, but not limited to, the semiconductive substrates described above.

[0020] Wafer 10 has been provided with an array of substantially electrically isolated word lines, such as the illustrated word lines 12, 14, and 16. Such word lines are of a conventional construction having a lowermost gate oxide, a lower polysilicon layer, an overlying silicide layer such as tungsten silicide, and insulating caps and side insulating spacers 18. Such

spacers and caps 18 preferably comprise an insulative nitride, such as Si_3N_4 . A thin layer 20 of Si_3N_4 or TetraEthylOrthoSilicate (TEOS) is provided atop the wafer to function as a diffusion barrier for subsequent BoroPhossoSilicate Glass (BPSG) deposition. Layer 20 has a thickness preferably from about 100 Angstroms to about 250 Angstroms.

[0021] Active areas are provided about the word lines, such as active regions 22, 24, and 26, to define an array of memory cell FETs. The discussion proceeds with reference to FETs formed using word lines 12 and 14, which would be provided with a capacitor construction for definition of two memory cells which share the same bit line contact. Active regions 22 and 26 define first active regions for electrical connection with a memory cell capacitor (described below). Active region 24 defines a second active region for electrical connection with a bit line (described below). Field oxide 19 is provided, as shown.

[0022] A first insulating layer 28 is provided over the word lines and active areas. An example material is BoroPhosphoSilicate Glass (BPSG), with an example deposition thickness being between 15,000 and 20,000 Angstroms. Preferably, as shown, layer 28 is subsequently planarized by chemical-mechanical polishing (CMP) to an elevation of from about 2,000 Angstroms to about 8,000 Angstroms above the word line nitride caps 18.

[0023] Referring to Figure 2, a series of first contact openings 38 and second contact openings 32 are provided through first insulating layer 28 to first active regions 22 and 26 and second active region 24, respectively. Selective photomasking and dry chemical etching of BPSG selectively relative to nitride would typically form such contact openings. An example etch chemistry would include CHF_3 and O_2 at low O_2 flow rate (i.e., less than 5% O_2 by volume in a CHF_3/O_2 mixture), or the combination of CF_4 , Argon, CH_2F_2 and CHF_3 .

[0024] Thereafter, a selective etch of the wafer is conducted to etch nitride layer 20 or TEOS relative to underlying silicon substrate 11 to upwardly expose active regions 22 and 24 and 26. The principal purpose of the nitride or TEOS layer 20 is to prevent diffusion of boron or phosphorous atoms from first insulating layer 28 into active areas 22 and 24 and 26. Caps 18 are preferably comprised of a nitride (Si_3N_4) and layer 28 comprised of an oxide, such that the contact etch to produce contact openings 32 and 38 will stop relative to word line spacers and caps 18.

[0025] In accordance with the invention, buried capacitor contact openings/containers 38 and associated pillars 40 can be provided along with the bit line contact openings 32 and pillars 34, as seen in Figures 3 and 4. A first layer of electrically conductive material 36 is provided over insulating material layer 28 to within first contact opening 32 and second contact opening 38 to electrically connect with first and second active regions 22, 26 and 24, respectively. First layer 36 is deposited to a thickness which fills first contact opening 32 and second contact opening 38. An example diameter for contact openings 32 and 38 is 0.2-0.25 micron. In such instance, an example preferred thickness of first layer 36 is less than 2,000 Angstroms, which is sufficient to fill the contact openings 32, 38. An example and preferred material for first layer 36 is in situ N+ doped polysilicon.

[0026] Wafer fragment 10 is planarized and etched downwardly at least to upper surface 30 of insulating material 28 to remove conductive material 36 there above. This will isolate first layer conductive material 36 within first contact openings 32 and 38. Such planarized etching can be conducted by plasma etchback, or by chemical-mechanical polishing.

[0027] Referring to Figure 5, the conductive material 36 within second contact opening 38 can be recessed further, to a level below upper surface 30 of insulating layer 28. A capacitor structure is formed at this location, as discussed below.

[0028] A layer of insulating material 54 is provided atop wafer 10. An example and preferred material for layer 54 is BPSG deposited to a thickness of approximately 10,000 Angstroms. Capacitor contact openings 56 are provided through insulating layer 54 to allow electrical connection with first active regions 22 and 26, through pillars 40.

[0029] Referring to Figure 6, a conductive material layer 58 is provided over insulating layer 54 and within capacitor contact opening 56. Conductive material layer 58 preferably comprises a storage node or storage container made from in situ phosphorous-doped HemiSpherical Grain (HSG) polysilicon.

[0030] CMP is preferably used to remove the conductive material layer 58 which is disposed atop insulating layer 54, thereby defining isolated storage node containers 62. The storage node containers 62 are electrically connected to first active regions 22 and 26 through pillars 40.

[0031] Referring to Figure 8, a conventional or other suitable capacitor cell dielectric layer 68, such as a cell nitride layer, is conformally deposited on the wafer 10 atop isolated storage node containers 62. Specifically, insulating layer 54 is interposed between the upper surface of pillar 34 and the capacitor cell dielectric layer 68.

[0032] A conductive capacitor cell layer 70, such as cell plate, is provided atop the capacitor cell dielectric layer 68, thereby defining an array of memory cell capacitors 72 on the wafer 10. Individual memory cell capacitors, such as the illustrated capacitors 72, of the array are thus provided within the capacitor contact openings, and are defined by an outwardly projecting container structure. Cell layer 70 preferably comprises in situ phosphorous-doped polysilicon and functions as a capacitor cell plate.

[0033] Cell layer 70 is then photopatterned with a layer of resist, which is intentionally illustrated herein with misalignment to account for the worst case scenario in a manufacturing environment. The misalignment will make the benefits of the present invention more apparent. Alternatively, an antireflective coating is added prior to photopatterning to assist in photolithography resolution. Subsequently, layers 68 and 70 are etched together.

[0034] The etch of the cell layer 70 has an isotropic component, i.e., the etch proceeds in both horizontal and vertical directions at relatively the same rate. The polysilicon layer that comprises cell layer 70 is selectively etchable with respect to the cell nitride layer 68. Hence, the cell nitride layer 68 is not etched at the same rate, and an overetch of the cell layer 70 results in an undercut profile. One consequence of the undercut of cell layer 70 is that, with a worst case scenario, photolithography may result in a misalignment edge 73, wherein the cell layer 70 is isotropically etched back past the upper edge of the conductive material layer 58.

[0035] One reason for undercutting into the cell layer 70 is to provide more of a process margin for the future bit line contact opening 80. The undercut profile helps to prevent the conductive polysilicon which forms cell layer 70 from projecting into the bit line contact opening 80 and thereby causing a short. This potential short is an increasing problem as the geometries of the DRAM cell become smaller and smaller. Therefore, one advantage of this step is an increased bit line contact opening 80 to cell layer 70 space and hence, a method to isolate the conductive edges of cell layer 70.

[0036] However, the corresponding disadvantage is that the cell layer 70 is etched past the conductive material layer 58, which leads to a low-level defect density of current leakage between the conductive material layer 58 and cell layer 70 at the misalignment edge 73. This current leakage results in loss of stored charge in the DRAM cell, which leads to data retention errors. Additionally, the loss of stored charge may be aggravated by possible damage of the exposed cell dielectric layer 68 in the misalignment edge 73 or region.

[0037] An electrically insulative layer 76, such as TEOS, is blanket deposited atop the wafer 10 (and therefore covers cell layer 70) to a thickness from about 150 Angstroms to about 1,500 Angstroms, preferably 500 Angstroms. The purpose of such a layer 76 is to cover both the exposed corner of the conductive material layer 58 and any damaged cell nitride layer 68. Further, the blanket TEOS film or layer 76 is superior to the use of a nitride film as it also allows hydrogen to diffuse through it and, consequently, does not prevent passivation by hydrogen of the FETs during alloy.

[0038] Continuing the process flow, Figure 10 illustrates a layer of insulating material 78 overlaying the electrically insulative layer 76 or barrier layer and underlying layers and capacitor structures 72. The insulating material 78 is preferably comprised of a BPSG layer 78. Alternatively, a deposited anti-reflective coating (not shown) may be added atop the BPSG layer 78 for increased photolithography resolution. The wafer 10 is coated with a layer of resist 79 and patterned.

[0039] Preliminary bit line contact openings 80 are provided through overlying BPSG layer 78, TEOS layer 76 and second BPSG layer 54 down to the pillar 34. The anisotropic plasma etch used to produce contact opening 80 is followed by a pre-metal clean, also known as a wet etch as oxide material is isotropically removed. The pre-metal clean/wet etch removes any anti-reflective coating (DARC) remaining on the top surface of the BPSG layer 78, and cleans the bottom of the contact opening 80.

[0040] Typically, the process incidentally would move out laterally when the wet etch process hits the cell nitride layer 68. However, the TEOS film 76 deposited atop of the wafer 10 after the cell layer 70 has been etched serves to substantially eliminate any preferential wet etching

along the seam of the cell nitride layer 68 and BPSG layer 78, which would occur if the TEOS layer 76 had not been deposited.

[0041] Without the TEOS layer 76, when the pre-metal clean/wet etch hits the cell nitride layer 68, an enhanced etch rate would occur along the interface with the BPSG layer 78. This enhanced etch rate is due to stress and dopant “pile-up” from the BPSG layer 78 and out diffusion from the heavily doped exposed cell layer 70. Higher out-diffusion and higher phosphorous concentration from the exposed cell layer 70 leads to an enhanced wet etch rate. This will be exacerbated by subsequent wet cleans prior to contact metal deposition, which can ultimately lead to bit contact-to-cell layer 70 shorts.

[0042] The presence of the TEOS layer 76 moves the stress away from the nitride/BPSG interface to the TEOS/BPSG interface. The result is that the cell layer 70 is no longer exposed during the pre-metal clean/wet etch. The TEOS film 76 prevents dopant mixing or “pile up” (an increase in the concentration of dopants in a particular location). Thus, the TEOS layer 76 provides a stress buffer and dopant barrier in the form of a TEOS film that is deposited after the capacitor cell plate 70 is etched and cleaned.

[0043] The addition of a TEOS film 76 buffers the stress as well as eliminates dopant mixing between the highly phosphorous doped polycrystalline silicon forming the capacitor cell layer 70 and the heavily doped BPSG layer 78 and, therefore, provides a method of reducing stress-induced wet etching along the BPSG/nitride interface in a DRAM capacitor to eliminate bit contact-to-cell layer 70 shorting.

[0044] Subsequently, a digit line layer, such as metal or conductively doped polysilicon, is provided atop the wafer 10 and within the complete bit line contact openings 80, and thus electrically connects with pillar 34 for establishing electrical connection with active region 24.

[0045] While the particular process as herein shown and disclosed in detail is fully capable of obtaining the objects and advantages hereinbefore stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as described in the appended claims.

[0046] One having ordinary skill in the art will realize that even though a DRAM was used as the illustrative example, the process is equally applicable to other semiconductor devices.

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